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SEVERE WEATHER GUIDE MEDITERRANEAN PORTS

23. TRIESTE



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Don Jacobs '87

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CONTENTS

Foreword	iii
Preface	v
Record of Changes	vii
1. GENERAL GUIDANCE	1-1
1.1 Design	1-1
1.1.1 Objectives	1-1
1.1.2 Approach	1-1
1.1.3 Organization	1-2
1.2 Contents of Specific Harbor Studies	1-3
2. Captain's Summary	2-1
3. General Information	3-1
3.1 Geographic Location	3-1
3.2 Qualitative Evaluation of the Port of Trieste.	3-4
3.3 Currents and Tides	3-4
3.4 Visibility	3-5
3.5 Winds and Weather	3-5
3.5.1 Bora	3-6
3.5.2 Scirocco	3-9
3.5.3 Genoa Lows	3-10
3.6 Seasonal Summary of Hazardous Weather Conditions	3-11
3.7 Local Indicators of Hazardous Weather Conditions	3-14
3.8 Protective and Mitigating Measures	3-15
3.9 Summary of Problems and Actions	3-16
References	3-21
Appendix A -- General Purpose Oceanographic Information	A-1

FOREWORD

This handbook on Mediterranean Ports was developed as part of an ongoing effort at the Naval Environmental Prediction Research Facility to create products for direct application to Fleet operations. The research was conducted in response to Commander Naval Oceanography Command (COMNAVOCEANCOM) requirements validated by the Chief of Naval Operations (OP-096).

As mentioned in the preface, the Mediterranean region is unique in that several areas exist where local winds can cause dangerous operating conditions. This handbook will provide the ship's captain with assistance in making decisions regarding the disposition of his ship when heavy winds and seas are encountered or forecast at various port locations.

Readers are urged to submit comments, suggestions for changes, deletions and/or additions to Naval Oceanography Command Center (NAVOCEANCOMCEN), Rota with a copy to the oceanographer, COMSIXTHFLT. They will then be passed on to the Naval Environmental Prediction Research Facility for review and incorporation as appropriate. This document will be a dynamic one, changing and improving as more and better information is obtained.

W. L. SHUTT
Commander, U.S. Navy

PORT INDEX

The following is a tentative prioritized list of Mediterranean Ports to be evaluated during the five-year period 1988-92, with ports grouped by expected year of the port study's publication. This list is subject to change as dictated by circumstances and periodic review.

1988 NO.	PORT	1990	PORT
1	GAETA, ITALY		TARANTO, ITALY
2	NAPLES, ITALY		ROTA, SPAIN
3	CATANIA, ITALY		SOUDA BAY, CRETE
4	AUGUSTA BAY, ITALY		PORT SAID, EGYPT
5	CAGLIARI, ITALY		ALEXANDRIA, EGYPT
6	LA MADDALENA, ITALY		ALGIERS, ALGERIA
7	MARSEILLE, FRANCE		TUNIS, TUNISIA
8	TOULON, FRANCE		GULF HAMMAMET, TUNISIA
9	VILLEFRANCHE, FRANCE		GULF OF GABES, TUNISIA
10	MALAGA, SPAIN		
11	NICE, FRANCE		
12	CANNES, FRANCE	1991	PORT
13	MONACO		
14	ASHDOD, ISRAEL		PIRAEUS, GREECE
15	HAIFA, ISRAEL		KALAMATA, GREECE
16	BARCELONA, SPAIN		THESSALONIKI, GREECE
17	PALMA, SPAIN		CORFU, GREECE
18	IBIZA, SPAIN		KITHIRA, GREECE
19	POLLENSA BAY, SPAIN		VALETTA, MALTA
20	LIVORNO, ITALY		LARNACA, CYPRUS
21	LA SPEZIA, ITALY		
22	VENICE, ITALY	1992	PORT
23	TRIESTE, ITALY		
24	CARTAGENA, SPAIN		ANTALYA, TURKEY
25	VALENCIA, SPAIN		ISKENDERUN, TURKEY
			IZMIR, TURKEY
1989	PORT		GOLCUK, TURKEY
			ISTANBUL, TURKEY
	SAN REMO, ITALY		GULF OF SOLLUM
	GENOA, ITALY		SPLIT, YUGOSLAVIA
	PALERMO, ITALY		DUBROVNIK, YUGOSLAVIA
	MESSINA, ITALY		
	TAORMINA, ITALY		
	PORTO TORRES, ITALY		
	BENIDORM, SPAIN		
	TANGIER, MOROCCO		

PREFACE

Environmental phenomena such as strong winds, high waves, restrictions to visibility and thunderstorms can be hazardous to critical Fleet operations. The cause and effect of several of these phenomena are unique to the Mediterranean region and some prior knowledge of their characteristics would be helpful to ship's captains. The intent of this publication is to provide guidance to the captains for assistance in decision making.

The Mediterranean Sea region is an area where complicated topographical features influence weather patterns. Katabatic winds will flow through restricted mountain gaps or valleys and, as a result of the venturi effect, strengthen to storm intensity in a short period of time. As these winds exit and flow over port regions and coastal areas, anchored ships with large 'sail areas' may be blown aground. Also, hazardous sea state conditions are created, posing a danger for small boats ferrying personnel to and from port. At the same time, adjacent areas may be relatively calm. A glance at current weather charts may not always reveal the causes for these local effects which vary drastically from point to point.

Because of the irregular coast line and numerous islands in the Mediterranean, swell can be refracted around such barriers and come from directions which vary greatly with the wind. Anchored ships may experience winds and seas from one direction and swell from a different direction. These conditions can be extremely hazardous for tendered vessels. Moderate to heavy swell may also propagate outward in advance of a storm resulting in uncomfortable and sometimes dangerous conditions, especially during tending, refueling and boating operations.

This handbook addresses the various weather conditions, their local cause and effect and suggests some evasive action to be taken if necessary. Most of the major ports in the Mediterranean will be covered in the handbook. A priority list, established by the Sixth Fleet, exists for the port studies conducted and this list will be followed as closely as possible in terms of scheduling publications.

[illegible]

1. GENERAL GUIDANCE

1.1 DESIGN

This handbook is designed to provide ship captains with a ready reference on hazardous weather and wave conditions in selected Mediterranean harbors. Section 2, the captain's summary, is an abbreviated version of section 3, the general information section intended for staff planners and meteorologists. Once section 3 has been read, it is not necessary to read section 2.

1.1.1 Objectives

The basic objective is to provide ship captains with a concise reference of hazards to ship activities that are caused by environmental conditions in various Mediterranean harbors, and to offer suggestions for precautionary and/or evasive actions. A secondary objective is to provide adequate background information on such hazards so that operational forecasters, or other interested parties, can quickly gain the local knowledge that is necessary to ensure high quality forecasts.

1.1.2 Approach

Information on harbor conditions and hazards was accumulated in the following manner:

- A. A literature search for reference material was performed.
- B. Cruise reports were reviewed.
- C. Navy personnel with current or previous area experience were interviewed.
- D. A preliminary report was developed which included questions on various local conditions in specific harbors.
- E. Port/harbor visits were made by NEPRF personnel; considerable information was obtained through interviews with local pilots, tug masters, etc; and local reference material was obtained.
- F. The cumulative information was reviewed, combined, and condensed for harbor studies.

1.1.3 Organization

The Handbook contains two sections for each harbor. The first section summarizes harbor conditions and is intended for use as a quick reference by ship captains, navigators, inport/at sea OOD's, and other interested personnel. This section contains:

- A. a brief narrative summary of environmental hazards,
- B. a table display of vessel location/situation, potential environmental hazard, effect-precautionary/evasion actions, and advance indicators of potential environmental hazards,
- C. local wind wave conditions, and
- D. tables depicting the wave conditions resulting from propagation of deep water swell into the harbor.

The swell propagation information includes percent occurrence, average duration, and the period of maximum wave energy within height ranges of greater than 3.3 feet and greater than 6.6 feet. The details on the generation of sea and swell information are provided in Appendix A.

The second section contains additional details and background information on seasonal hazardous conditions. This section is directed to personnel who have a need for additional insights on environmental hazards and related weather events.

1.2 CONTENTS OF SPECIFIC HARBOR STUDIES

This handbook specifically addresses potential wind and wave related hazards to ships operating in various Mediterranean ports utilized by the U.S. Navy. It does not contain general purpose climatology and/or comprehensive forecast rules for weather conditions of a more benign nature.

The contents are intended for use in both pre-visit planning and in situ problem solving by either mariners or environmentalists. Potential hazards related to both weather and waves are addressed. The oceanographic information includes some rather unique information relating to deep water swell propagating into harbor shallow water areas.

Emphasis is placed on the hazards related to wind, wind waves, and the propagation of deep water swell into the harbor areas. Various vessel locations/situations are considered, including moored, nesting, anchored, arriving/departing, and small boat operations. The potential problems and suggested precautionary/evasive actions for various combinations of environmental threats and vessel location/situation are provided. Local indicators of environmental hazards and possible evasion techniques are summarized for various scenarios.

CAUTIONARY NOTE: In September 1985 Hurricane Gloria raked the Norfolk, VA area while several US Navy ships were anchored on the muddy bottom of Chesapeake Bay. One important fact was revealed during this incident: Most all ships frigate size and larger dragged anchor, some more than others, in winds of over 50 knots. As winds and waves increased, ships 'fell into' the wave troughs, BROADSIDE TO THE WIND and become difficult or impossible to control.

This was a rare instance in which several ships of recent design were exposed to the same storm and much effort was put into the documentation of lessons learned. Chief among these was the suggestion to evade at sea rather than remain anchored at port whenever winds of such intensity were forecast.

2. CAPTAIN'S SUMMARY

The city of Trieste is located at the head of the Adriatic Sea, at the southern end of a long, narrow strip of coastal territory administered by Italy. To the northeast of the city is a range of rocky hills rising to heights over 1000 ft (305 m), adjacent to a plateau extending into Yugoslavia (Figure 2-1).



Figure 2-1. Western Mediterranean Sea.

The Port of Trieste is located at $45^{\circ} 38' N$ $13^{\circ} 45' E$. There are two primary anchorage areas, marked A1 and A2 on Figure 2-2. At both anchorages, depths are 59 ft. (18 m) and holding ground is fair to poor.

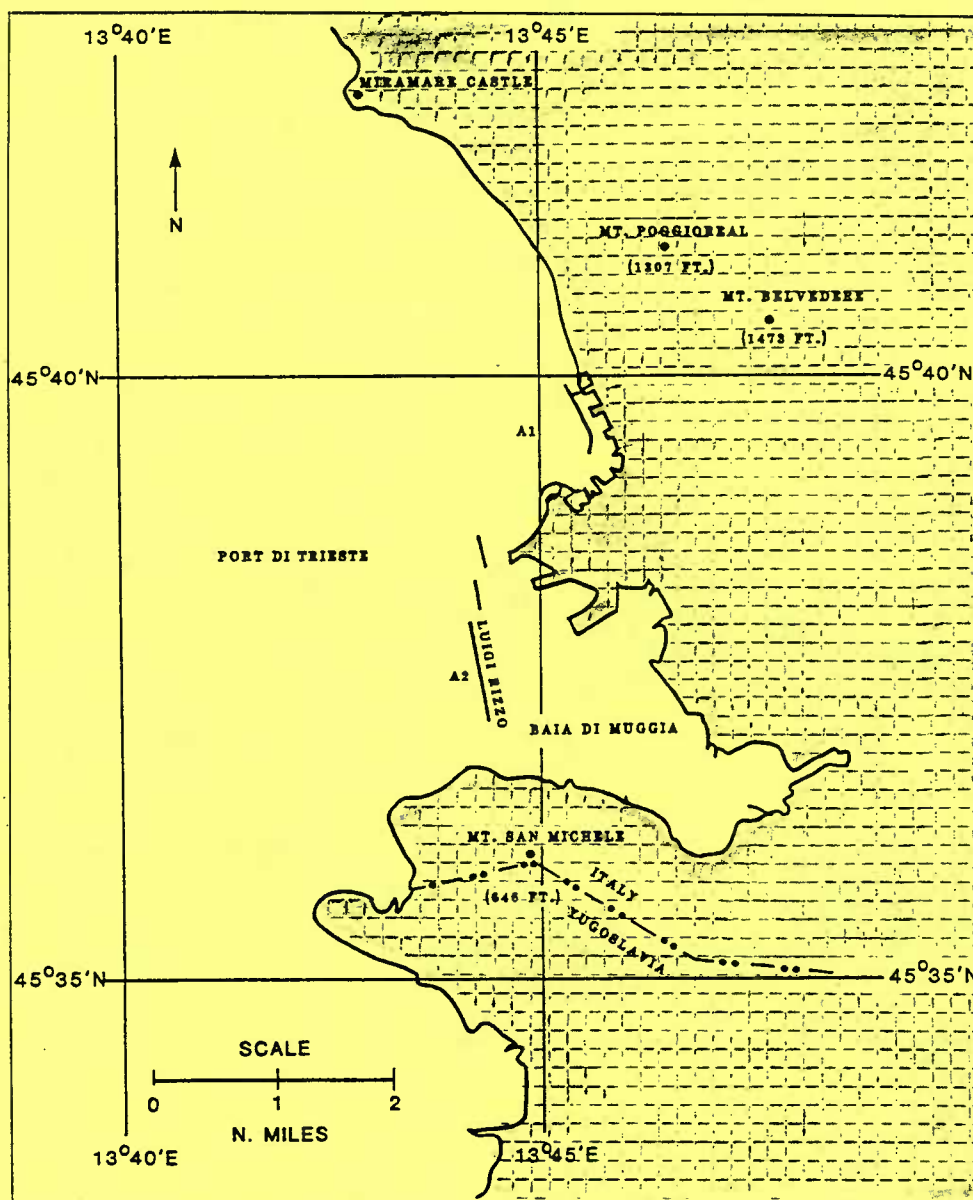


Figure 2-2. Trieste Region.

The harbor is divided into three large areas: the commercial port, the industrial port, and the oil harbor. The commercial port is formed by four free zones: Porto Franco Vecchio (Old Free Zone), Porto Franco Nuovo (New Free Zone), Scalo Legnami (Timber Dock) and Porto Franco Oli Minerali (Mineral Oil Dock) (FICEURLANT, 1987) (Figure 2-3). When entering Porto Franco Vecchio, the south entrance, approximately 518 ft (158 m) wide, is used. Ships may enter Porto Franco Nuovo from either the north or south entrance.

The main U.S. Navy berth is at the Stazione Maritima (Maritime Station) as is the fleet landing. Draft on the north side of the pier is 30 ft (9 m) and 27 ft (8.2 m) on the south side. The pier is 825 ft (251 m) long and is made of concrete. Some of the mooring dolphins have worn caps (August 1987) and lines tend to slip up and off during heavy weather, especially during a Bora outbreak. Secondary berths are at the grain elevator pier (Molo VI) and at Scalo Legnami. Molo VII can facilitate large ships (40+ ft draft) but as of August 1987, expansion construction was in progress limiting the pier's use. Most of the piers are aligned in the direction of the Bora wind so ships can arrive and depart in winds as high as 40 kts. Note that the Maritime Station berth is not aligned with the Bora wind direction (east-northeast).

Tidal range in Trieste is 2.8 ft (.85 m) and the current at the port entrance is less than a kt. South of the port, along the Yugoslav coast, a one kt current sets northward.

Specific hazardous environmental conditions, vessel situations, and suggested precautionary/evasion action scenarios for the Port of Trieste are summarized in Table 2-1.

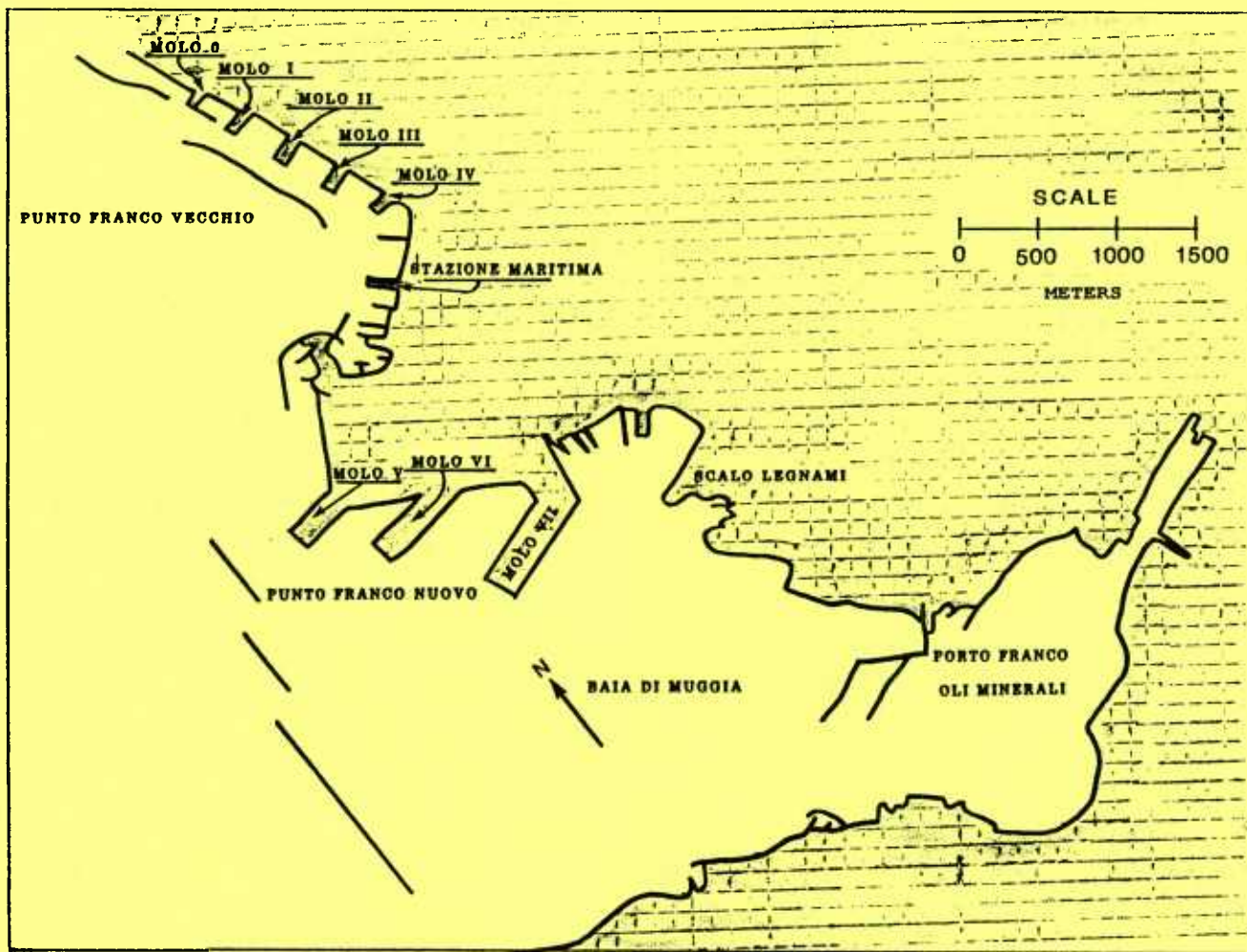


Figure 2-3. Port of Trieste.

Table 2-1. Summary of hazardous environmental conditions for the Port of Trieste, Italy

HAZARDOUS CONDITION	INDICATORS OF POTENTIAL HAZARD	VESSEL LOCATION/ SITUATION AFFECTED	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS
<p>1. ENE'ly winds - Bora</p> <ul style="list-style-type: none"> * Strong winds affecting the entire Adriatic. * Occurs year-round - most common in cool season. Worst month is Feb. * 50 kt gusting to 80 kt common in winter. * Wave heights are limited due to terrain. * Weakest at noon, strongest at sunrise and sunset. 	<p><u>Advance Warning</u></p> <ul style="list-style-type: none"> * Clouds atop the mountains to the north will sometimes precede onset of Bora winds. * Bora can be expected after 24 hr or so of southeasterly winds, often with rain. * Normally, southeasterlies last 6 hr or less. * Strongest winds usually not at onset. 	<p>(1) <u>Moored - inner harbor.</u></p> <p>(2) <u>Anchorage.</u></p> <p>(3) <u>Arriving/Departing.</u></p> <p>(4) <u>Small Boats.</u></p>	<p>a. Winds, more than waves, will affect berthed ships.</p> <ul style="list-style-type: none"> * Adding lines is most effective measure to take. * Although primary U.S. Navy pier (Maritime Station) is not, most other piers are aligned with Bora wind direction (ENE) and ships ride out Bora wind with little difficulty. <p>b. Wind chill factors can be hazardous in winter and early spring.</p> <p>a. Winds with moderate waves will affect anchored ships.</p> <ul style="list-style-type: none"> * It is best to protect at sea during Bora episode. * High winds will cause dragging of anchor with mud bottom. * It is possible to limit waves substantially and winds slightly by maneuvering close to coastline - north of Trieste. South of the port the Yugoslavian two-mile territorial claim limits approach to the coast. <u>Caution:</u> North of the port, there are mussel farms near shore. Consult latest charts. <p>b. Wind chill factors can be hazardous during winter and early spring.</p> <p>a. Ships with large sail area will have difficulty but others can be berthed in winds up to 40 kt at most berths except Maritime Station.</p> <ul style="list-style-type: none"> * Winds and waves will be higher to sea than in harbor. <p>b. Wind chill factors can be hazardous during winter and early spring.</p> <p>a. Fleet landing at Maritime Station is well sheltered.</p> <ul style="list-style-type: none"> * Because waves are not excessive except in the most severe Boras, boating can normally continue. * Low freeboard boats may have difficulty loading and offloading at fleet landing during strong Bora, especially if coincident with low tide. <p>b. Wind chill factors can be hazardous during winter and early spring.</p>
<p>2. S'ly winds - Scirocco</p> <ul style="list-style-type: none"> * Usually cover the entire Adriatic. * Winds are cool in winter, hot in summer. * Occurs year-round. * 30 kt gusting to 45 kt common. 	<p><u>Advance Warning</u></p> <ul style="list-style-type: none"> * Onset much more gradual than Bora onset and winds not as intense. * Low pressure center approaching from west or south will cause a Scirocco. 	<p>(1) <u>Moored - inner harbor.</u></p> <p>(2) <u>Anchorage.</u></p> <p>(3) <u>Arriving/Departing.</u></p> <p>(4) <u>Small Boats.</u></p>	<p>a. Wind may be stronger in Muggia Bay due to funneling.</p> <ul style="list-style-type: none"> * Harbor is protected from high waves. * Adding lines normally sufficient protection measure. <p>a. Waves are higher at anchorage than in harbor.</p> <ul style="list-style-type: none"> * Ships with large sail area should protect at sea. * Otherwise, riding out at anchor, except in most severe Sciroccos, can be accomplished. * High winds will cause dragging of anchor with mud bottom. <p>a. Waves toward sea higher than in harbor area.</p> <ul style="list-style-type: none"> * Ships with large sail area should delay berthing. <p>a. Fleet landing is well sheltered.</p> <ul style="list-style-type: none"> * Because waves are not excessive in port area, boating can continue in high winds. * Low freeboard boats may have difficulty in loading and offloading at Fleet Landing during low tide.

SEASONAL SUMMARY OF TRIESTE HAZARDOUS WEATHER CONDITIONS

(Much of this information is adapted from Brody and Nestor, 1980).

WINTER (November through February):

- * Bora winds occur year-round with February the peak month. Winds of 50 kt with gusts to 80 kt are not uncommon.
- * Strong southerly winds can occur with frontal passages.
- * Below freezing temperatures combined with Bora winds cause hazardous wind chill factors.
- * Fog-laden west winds cause visibility restrictions. One day per year, usually in November, expect visibility to be less than one mile.

SPRING (March through May):

- * Early spring similar to winter. Strong Bora episodes are rare after March.
- * Some visibility restrictions possible, usually caused by fog associated with a west wind.
- * Thunderstorms, though infrequent, start occurring.

SUMMER (June thru September):

- * Bora winds still possible but winds usually less than 30 kt.
- * Thunderstorms more frequent but are normally short lived.

AUTUMN (October):

- * Short transition season as winter weather returns by end of month.
- * Wind chill not a factor until late November.

NOTE: For more detailed information on hazardous weather conditions see previous Summary Table in this section and Hazardous Weather Summary in Section 3.

REFERENCES

Brody, L.R. and M.J.R. Nestor, 1980: Regional Forecasting Aids for the Mediterranean Basin, NAVENVPREDRSCHFAC Technical Report TR 80-10. Naval Environmental Prediction Research Facility, Monterey, California 93943-5006.

FICEURLANT, 1987: Port Directory for Trieste, Italy (1986). Fleet Intelligence Center Europe and Atlantic, Norfolk, Virginia.

3. GENERAL INFORMATION

The information in this section is intended for Fleet meteorologists/oceanographers and staff planners. Paragraph 3.5 provides a general discussion of winds and weather and Table 3-2 presents a summary of hazards and actions by season.

3.1 Geographic Location

The city of Trieste is located at the head of the Adriatic Sea, at the southern end of a long, narrow, coastal strip of Italy. To the northeast of the city a range of rocky hills rise to heights over 1000 ft (305 m) and extend as a plateau into Yugoslavia (Figure 3-1).

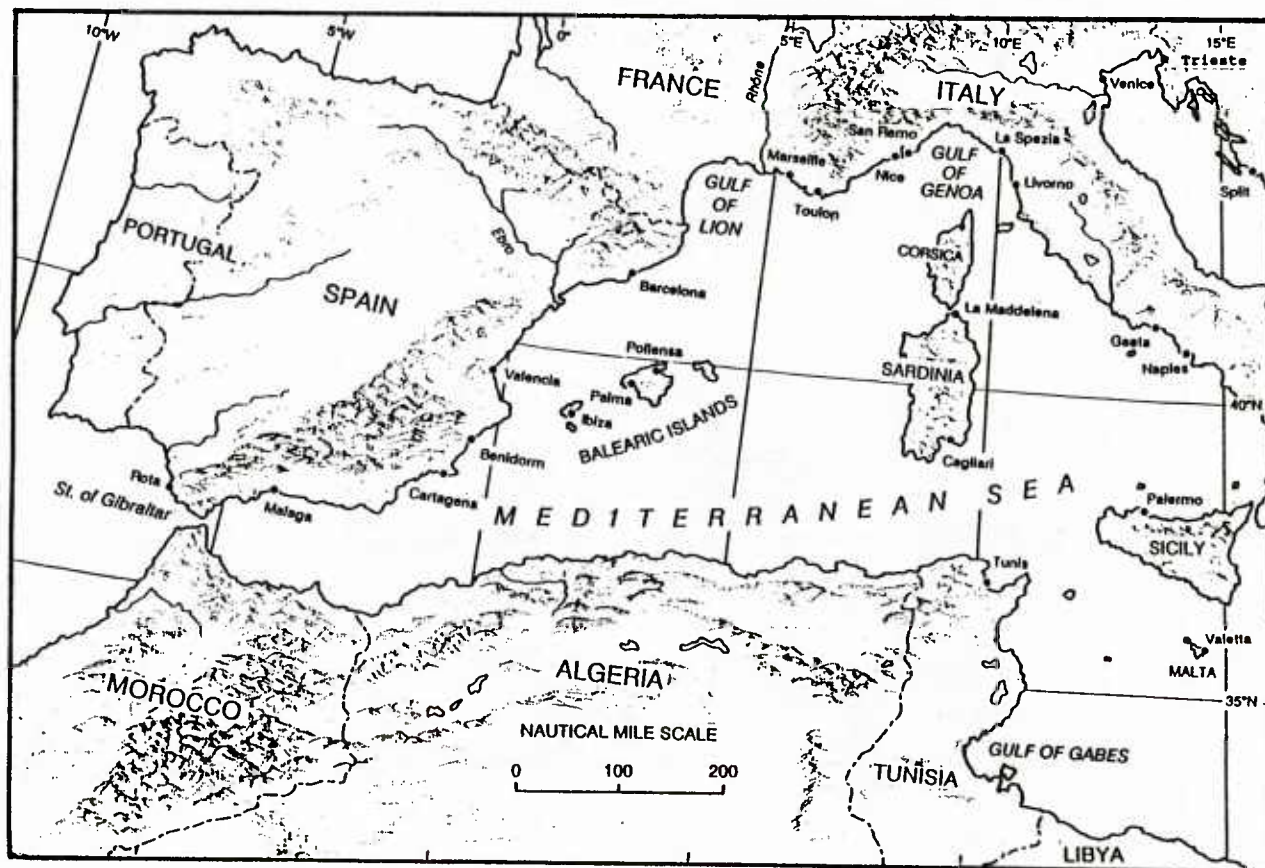


Figure 3-1. Western Mediterranean Sea.

The Port of Trieste is located at $45^{\circ} 38'N$ $13^{\circ} 45'E$. There are two primary anchorage areas, marked A1 and A2 on Figure 3-2. At both anchorages, depths are 59 ft (18 m) and holding ground is fair to poor.

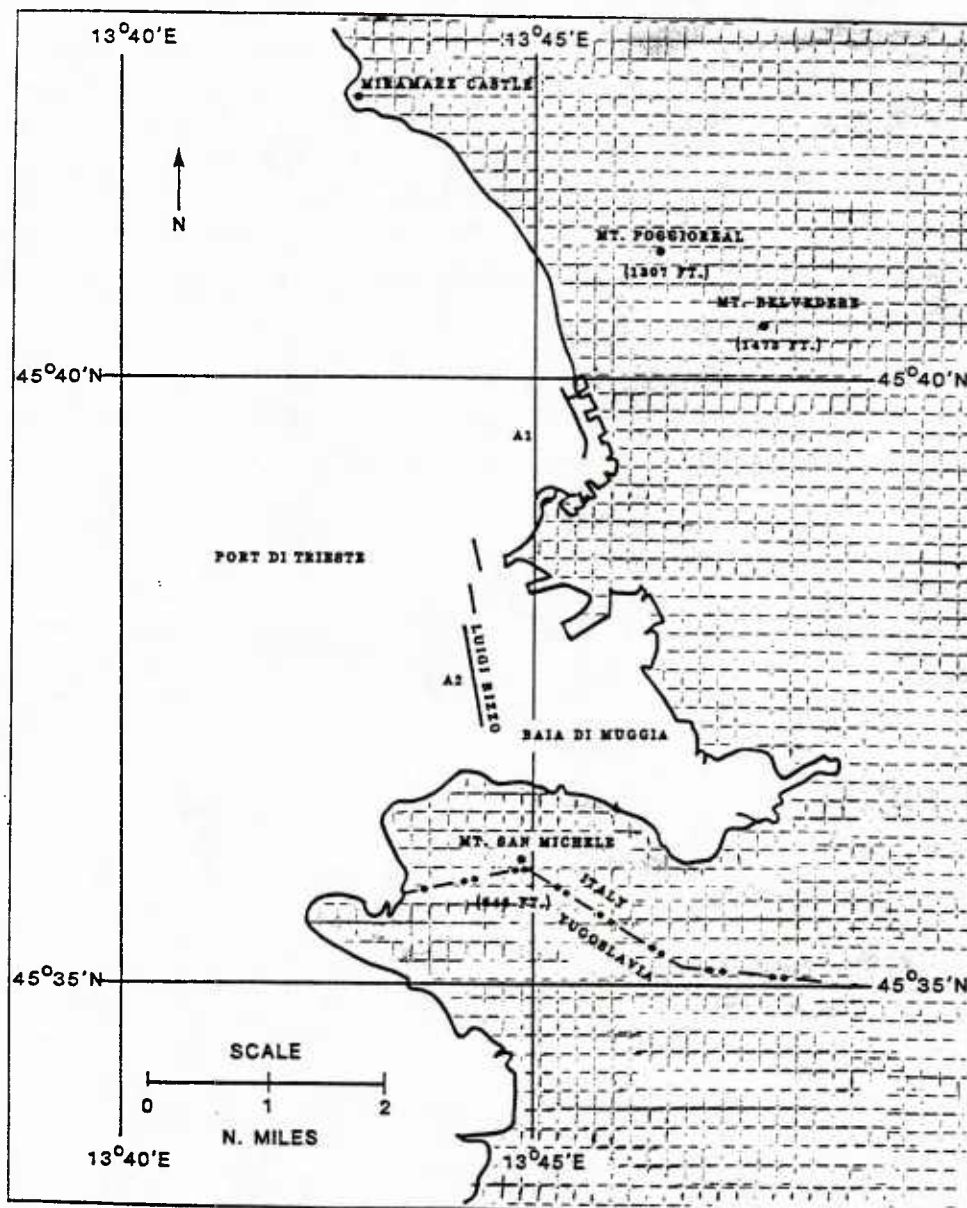


Figure 3-2. Trieste Region.

The harbor is divided into three large areas: the commercial port, the industrial port, and the oil harbor. The commercial port, shown in figure 3-3, is formed by four free zones: Porto Franco Vecchio (Old Free Zone), Porto Franco Nuovo (New Free Zone), Scalo Legnami (Timber Dock), and Porto Franco Oli Minerali (Mineral Oil Dock) (FICEURLANT, 1987). When entering Porto Franco Vecchio the approximately 518 ft (158 m) wide south entrance is used. Ships may enter Porto Franco Nuovo through either the north or south entrance.

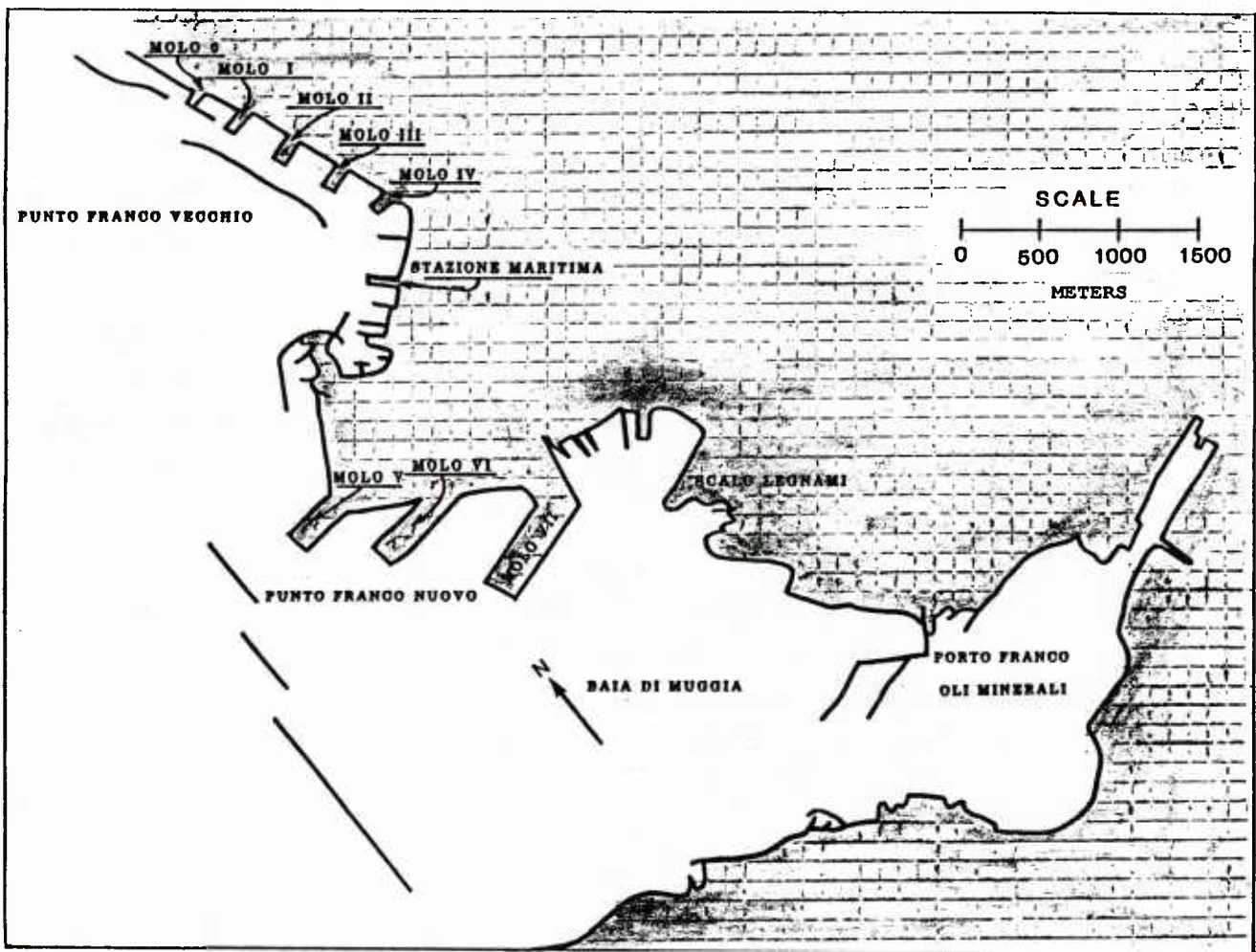


Figure 3-3. Port of Trieste.

Qualitative Evaluation of the Port of Trieste

The Port of Trieste is an area of frequent Bora wind occurrences and is near the Trieste Gap where winds are frequently over 50 kt during Bora episodes. However, because the winds are from the direction of the land mass, wave heights are not extreme and many port operations can continue except during the most severe Bora outbreaks. The port is also protected from the Scirocco wind (southeasterly) and minimal wave heights occur with Scirocco events.

The main U.S. Navy berth is at the Stazione Maritima (Maritime Station) as is the fleet landing. Draft on the north side of the pier is 30 ft (9 m) and 27 ft (8.2 m) on the south side. The pier is 825 ft (251 m) long and is made of concrete. Some of the mooring dolphins have worn caps (August 1987) and lines tend to slip up and off during heavy weather, especially during a Bora outbreak. Secondary berths are at the grain elevator pier (Molo VI) and at Scalo Legnami. Molo VII can facilitate large ships (40+ ft draft) but as of August 1987, expansion construction was in progress limiting the pier's use. Most of the piers are aligned in the direction of the Bora wind so ships can arrive and depart in winds as high as 40 kts. Note that the Maritime Station berth is not aligned with the Bora wind direction (east-northeasterly).

Currents and Tides

There is a large counterclockwise current gyre in the center of the Adriatic Sea which sometimes breaks

into two smaller gyres. In any case, the general current flow is northward along the eastern shores and southward along the western shores. Very little surface current is noted in the port area of Trieste. Just south of the port, along the Yugoslavian coast, a one kt current sets northward (Italian Oceanographic Institute, 1982). Astronomical tide range at the port is 2.8 ft (.85 m).

3.4 Visibility

Visibility is generally good in Trieste. The Bora wind normally brings dry, clean air which can persist for days at a time in the winter. However, Trieste is not far from a major source of fog, the Po Valley and the Gulf of Venice. During periods of westerly winds fog will advect in from these areas and reduce the visibility at Trieste to less than one mile, usually one or two days per year in November. Another two or three days per year, visibility will be in the 1 to 3 mile range. Although these episodes of reduced visibility are rare, they can last all day when they do occur.

3.5 Wind and Weather

Trieste's climate is dominated by the Bora wind which can occur any time during the year. However, the peak frequency occurs in the cold season (November-March). To a lesser extent, the Scirocco wind affects Trieste but is not nearly as strong or as frequent as the Bora. Gulf of Genoa lows have an influence on weather in the northern Adriatic Sea as they either move

toward Trieste causing stormy weather with clouds and rain, or they move southeastward causing a pressure differential at Trieste and trigger a Bora outbreak. Much of the following information is adapted from Brody and Nestor, 1980.

3.5.1 Bora

The Bora occurs when cold air accumulates over the Balkan Peninsula, especially Yugoslavia. When the depth of the cold air pool reaches the height of the mountain passes, the Bora will commence. There are two primary weather patterns associated with the Bora:

- (1) Anticyclonic Pattern: A large high pressure center is present over central Europe without a well defined low to the south.
- (2) Cyclonic Pattern: A low pressure center is present in the southern Adriatic Sea or in the Ionian Sea.

In either case, the pressure is higher on the European side of the mountains and lower on the Mediterranean side.

The Bora is most common in the Adriatic Sea where it flows mainly from the northeast through gaps in the Dinaric Alps. One of these gaps is near Trieste and is known as the Trieste Gap. On occasion, the Bora can be very localized, extending only a few miles offshore.

At other times, the Bora will dominate the entire Adriatic Sea and, when the pressure differential is large enough, the Bora can extend as far south as Malta.

In the northern Adriatic, the wind direction associated with the Bora is generally northeasterly but can vary in local areas due to the terrain. The Bora at Trieste is east-northeasterly. It is more northerly further south and even northwesterly along Italy's southeast coast. The strongest winds occur along the eastern shore of the Adriatic from Trieste to the Albanian border. It is most intense to the north, decreasing somewhat moving southward. The greatest intensity of the Bora occurs where the mountain peaks are at least 2000 ft above sea level and not more than two or three miles inland. Over the open water of the Adriatic, winds are usually less intense, but gale force winds (30+ kt) are common. The frequency of the gale force Bora in the open sea is greater for the cyclonic type of pattern than for the anticyclonic pattern. During the cyclonic pattern, the strongest winds are usually found in the southern Adriatic.

Bora winds are most common during the cool season (November through March). In Trieste, the highest frequency of occurrence and strongest winds are in February. In general, the frequency of gale force winds varies from one day per month, or less, in the summer to six days per month during winter months. The average duration of a continuous gale force Bora over the Adriatic is about 12 hours but the winds sometimes will last up to two days. The average duration of a Bora that reaches gale force some time during its history is 40 hours with a maximum duration of 5 days. At Trieste, the average duration of a gale force Bora

varies from three days in winter to one day in summer. Local mariners state that the Bora will last an odd number of days; 1, 3, 5, etc. However, the Bora has been known to last for up to 30 days at Trieste without a significant lull.

In 1956 a gust of 125 kt was recorded at Trieste. However, in a recent 10 year period from the mid-70's to the mid-80's the highest gust recorded was 95 kt. In the Trieste area, the Bora does not usually start with a sudden blast but will build up at a relatively moderate pace - a 60 kt Bora will not reach peak intensity during the first 3 or 4 hours. This may allow time for some protective measures to be assessed and conducted. Wave heights near the port of Trieste are normally not high with a Bora as the terrain limits the fetch. Because most of the piers are aligned with the direction of the Bora, certain ships can be berthed during a Bora episode, even with winds of 40 kt. Note that the primary US Navy berth, the Maritime Station Pier, is not aligned with the Bora direction.

There is a noticeable diurnal variation at coastal Adriatic stations during Bora conditions. During the day, along the eastern shore, the sea breeze counteracts the offshore flow of the Bora which leads to a decrease in the strength of the Bora between 1200L and 1800L. In Trieste, winds are weakest at noon and strongest at sunrise and sunset. With the anticyclonic pattern, the Bora is basically a dry wind due to its katabatic nature. Clear skies and good visibilities are found in the lee of the mountains while thick clouds associated with upslope motions are found on the mountain crests. These clouds sub-sequently dissipate

in the descending air on the lee side. With the cyclonic pattern, the Bora is often accompanied by low clouds and reduced visibilities associated with rain and/or drizzle. These conditions are more noticeable over the open water areas than along the coastal zone.

3.5.2 Scirocco

The Scirocco is a southeasterly to southwesterly wind over the Mediterranean originating over North Africa, sometimes affecting the Adriatic Sea area. The Scirocco tends to occur year-round without a favored month or season. The Scirocco normally occurs within the warm sector of a cyclone passing either north or west of the region. These cyclones originate either over North Africa or south of the Alps, primarily in the Gulf of Genoa in the latter case. Scirocco conditions occur in the Gulf of Genoa case when the circulation extends far enough southward to draw air from the North African region. The onset of the Scirocco is more gradual than the onset of a Bora. It occurs more frequently in the southern part of the Adriatic with a decrease in frequency northward. Although the Scirocco is not as strong as the Bora, winds can reach gale force (30+ kt), especially in winter and spring. The average duration of continuous gale force winds during a Scirocco is 10 to 12 hours and occasionally as long as 36 hours. The maximum wind speed likely during a Scirocco is about 55 kt.

At Trieste, local terrain features alter the effect of the Scirocco. Winds will parallel the coast in general and sometimes reach the port through a small river valley which terminates just south of the port area in the Baia de Muggia (Figure 3-3). The valley winds are normally stronger than the coastal winds. In August 1985, a gust of 90 kt was recorded as a 1003 mb low tracked across Italy into the northern Adriatic. This high wind was most likely due to a combination of the venturi effect from the valley and the effects of a barrier such as an elevated land mass. As the front approaches from a relatively flat, low surface, such as the ocean, toward an elevated land mass, supergradient winds will occur, again due to the venturi effect. These winds are restricted to a narrow band between the front and the landmass. Seas are usually not high with strong southeasterlies due to protection from the terrain. Also, these winds do not normally sustain for long periods of time.

3.5.3 Genoa Lows

Genoa Lows are low-pressure systems which develop to the south of the Alps in the region incorporating the Gulf of Genoa, Ligurian Sea, Po Valley, Gulf of Venice and northern Adriatic Sea. Although several factors are important in cyclogenesis, the development of the cyclone near the Gulf of Venice - as opposed to the west near the Gulf of Genoa - depends on the amount of cold air penetrating the Po Valley from the northeast. If there is little or no cold air entering the Po Valley, the low will probably form in the Gulf of Venice; otherwise, cyclogenesis will occur to the west.

Genoa cyclones usually remain stationary (or at least leave a residual trough) south of the Alps throughout their life history. If the lows do move, they generally follow one of two tracks. The first track, common for cyclones developing in the Gulf of Venice, is a northeasterly to north-northeasterly direction across the Alps. This track is associated with strong southwesterly flow aloft. In this case, Scirocco conditions are likely if the circulation of the low extends southward into North Africa, allowing air from the desert source to move northward. The second track, associated with a strong anticyclone over the Balkans, Turkey and the Black Sea is in a southeasterly direction from the Gulf of Genoa towards the Ionian Sea. In this case, a gale force Bora is extremely likely by the time the depression moves into the Ionian Sea.

3.6

Seasonal Summary of Hazardous Weather Conditions

The seasonal weather patterns in the Adriatic Sea area are controlled to a large extent by the monsoonal behavior of the Eurasia land mass. During the winter, the Siberian High develops and extends southwestward towards the Balkans. Cold Bora winds are the usual result of this pattern. Stormy and unsettled weather is also common during the winter with a high frequency of lows moving into this area. Much of the following information is adapted from Brody and Nestor, 1980.

A. WINTER (November through February)

Bora winds are common in Trieste during wintertime. Winds of 50 kt with occasional gusts to

80 kt are not uncommon. In 1956 a gust of 125 kt was recorded. However, in more recent years the highest gust has been 95 kt. Peak month for Bora occurrence is February while strong winds associated with the Bora can occur in any month. Other strong winds, usually from the south, can occur prior to cold frontal passage associated with a transitory low pressure system from the Gulf of Genoa.

Below freezing temperatures are common during winter. Wind chill factors can be dangerous when cold temperatures occur with high winds, quite common in a Bora outbreak. See Table 3-1 for computation of wind chill values.

Trieste normally experiences good visibility year-round. However, one or two days per year, usually in November, expect visibility to be near zero in dense fog. The fog is associated with a west wind and can last the entire day. On another two or three days visibility will be in the 1 to 3 mile range, again associated with fog and a west wind.

Table 3-1. Wind Chill. The cooling power of the wind expressed as "Equivalent Chill Temperature" (adapted from Kotsch, 1983).

Wind Speed		Cooling Power of Wind expressed as "Equivalent Chill Temperature"									
Knots	MPH	Temperature (°F)									
Calm	Calm	40	35	30	25	20	15	10	5	0	
Equivalent Chill Temperature											
3-6	5	35	30	25	20	15	10	5	0	-5	
7-10	10	30	20	15	10	5	0	-10	-15	-20	
11-15	15	25	15	10	0	-5	-10	-20	-25	-30	
16-19	20	20	10	5	0	-10	-15	-25	-30	-35	
20-23	25	15	10	0	-5	-15	-20	-30	-35	-45	
24-28	30	10	5	0	-10	-20	-25	-30	-40	-50	
29-32	35	10	5	-5	-10	-20	-30	-35	-40	-50	
33-36	40	10	0	-5	-15	-20	-30	-35	-45	-55	

B. Spring (March through May)

Early spring resembles winter and as spring progresses some summer like days are noted. The strong Bora episodes usually end by April but milder Boras can occur in any month of the year.

Some visibility restrictions can occur with fog in the early spring. This is usually due to a fog laden west wind and can last for a day or so. Wind chill is still a factor during early spring.

C. SUMMER (June through September)

The Siberian High is replaced by a large low pressure system extending from Southwest Asia toward Asia Minor. This pressure configuration brings generally warm and dry weather to Trieste. When Bora winds do occur, wind speeds are usually less than 30 kt.

Thunderstorms are most frequent during the summer months. Due to the hilly topography around Trieste, these storms will occasionally form over the coastal terrain and move over the port area. Generally, thunderstorms are short lived in the Trieste region.

D. AUTUMN (October)

The autumn season in the Adriatic is short, lasting only for the month of October and is characterized by an abrupt change to winter-like weather. Wind chill is normally not a factor until late November.

3.7 Local Indicators of Hazardous Weather Conditions

There are few local indicators of the Bora. Because the wind is usually dry, there are no cloud patterns occurring at Trieste prior to a Bora onset. However, there are often clouds atop the mountains to the north before a Bora event. These clouds will have an east-to-west movement which precedes the Bora onset by an hour or two. Another tip-off used by local mariners is that after a solid day of southeasterlies, they expect a Bora wind the next day. Unfortunately, most of the time when a brisk, cold wind is experienced, the Bora has already started without much warning. The strongest winds, however, are usually not in the beginning stages of the Bora event so there may be time for protective measures to be taken. Also, there are some general guidelines to use when other than local observations are available.

The following "forecaster hints" are adapted from Brody and Nestor, 1980:

- o Expect Bora conditions in the Adriatic Sea when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian Sea, especially from the Gulf of Genoa.
- o When Bora conditions are occurring, a well-defined foehn wall cloud over the Dinaric Alps can be seen in satellite imagery. Also, cumulus cloud streaks over the water will indicate gale force (30+ kt) Bora winds are present.

Likewise, there are very few hints available for predicting the onset of a Scirocco. However, the Scirocco's onset is much more gradual than the Bora and it is usually not as intense. One rule, almost foolproof, is that the Scirocco is normally associated with a depression or cyclone which approaches the northern Adriatic Sea from the west or south.

3.8 Protective and Mitigating Measures

In most bad weather instances in Trieste, wind will be the dominating factor rather than waves although some local seas will build even in a limited fetch. Most of the harbor area is protected by the local terrain. During an intense Bora event, if at anchorage, it is best to go to sea. If berthed--add lines.

One maneuver to decrease the effect of the local seas during a severe Bora is to get as close to the coastline as possible, in the lee of the high terrain.

However, south of the port is the Yugoslavian coast with a two-mile territorial limit. The recommended location is north of Castella Miramare (Figure 3-2), moving to within one-half mile of the coast. Consult charts, as there are mussel farms in this area. This maneuver will decrease seas substantially and decrease winds slightly.

3.9

Summary of Problems and Actions

Table 3-2 is intended to provide easy to use seasonal references for meteorologists on ships using the port of Trieste. Table 2-1 (Section 2) summarizes Table 3-2 and is intended primarily for use by ship captains.

Table 3-2. Potential problem situations at Port of Trieste, Italy - ALL SEASONS

VESSEL LOCATION/ SITUATION AFFECTED	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
<p><u>1. Moored-inner harbor</u></p> <p>Occurs year-round but most common in cool season. Feb is worst month.</p> <p>Occurs year-round.</p>	<p>a. ENE'ly winds - Bora Strong winds with limited waves heights. 50 kt gusting to 80 kt common in winter.</p> <p>b. S'ly winds - Scirocco Winds which usually cover the Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common.</p>	<p>a. Winds, more so than waves, will affect berthed ships. Adding lines is most effective measure to take. Note that the mooring dolphins at Maritime Station have worn caps and lines may slip in heavy weather. Most piers are aligned with the Bora (ENE) wind direction and ships ride out the Bora with little difficulty. Unfortunately, the primary U.S. Navy pier - Maritime Station is not aligned as such. Wind chill hazards are potentially dangerous in winter and early spring.</p> <p>b. Wind can be stronger in Muggia Bay due to funneling. Most of harbor area protected from high waves during Scirocco. Adding lines at berth is normally sufficient protection.</p>	<p>a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Weakest at noon, strongest at sunrise and sunset.</p> <p>b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists.</p>
<p><u>2. Anchorage</u></p> <p>Occurs year-round but most common in cool season. Feb is worst month.</p> <p>Occurs year-round.</p>	<p>a. ENE'ly winds - Bora Strong winds with limited waves heights. 50 kt gusting to 80 kt common in winter.</p> <p>b. S'ly winds - Scirocco Winds which usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common.</p>	<p>a. Winds with moderate waves will affect anchored ships and, normally, it is best to protect at sea if possible during a Bora. High winds will cause dragging of anchor with mud bottom. It is possible to limit wave heights substantially and wind speeds slightly by maneuvering close to the coastline - NORTH OF THE PORT. South of the port is the Yugoslavian two-mile territorial claim limits approach to the coast. CAUTION: North of the port, there are mussel farms near shore. Consult latest charts.</p> <p>b. The configuration of the terrain protects the harbor and the anchorage from extreme waves; waves are higher at anchorage than in the harbor. Ships with large sail area should protect at sea, others usually ride it out at anchor, except in the most severe Scirocco. High winds will cause dragging of anchor with mud bottom.</p>	<p>a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Weakest at noon, strongest at sunrise and sunset.</p> <p>b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists.</p>

Table 3-2. (Continued)

VESSEL LOCATION/SITUATION	POTENTIAL HAZARD	EFFECT - PRECAUTIONARY/EVASIVE ACTIONS	ADVANCE INDICATORS AND OTHER INFORMATION ABOUT POTENTIAL HAZARD
<p>3. <u>Arriving/Departing</u></p> <p>Occurs year-round but most common in cool season. Feb is worst month.</p> <p>Occurs year-round.</p>	<p>a. ENE'ly winds - Bora Strong winds with limited waves heights. 50 kt gusting to 80 kt common in winter.</p> <p>b. S'ly winds - Scirocco Winds usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt are common.</p>	<p>a. Ships with large sail area will have difficulty but others can be berthed in winds up to 40 kt at most berths except Maritime Station. On departure, expect wave heights to increase seaward. Winds may be somewhat stronger too, as distance from blocking terrain increases.</p> <p>b. Ships with large sail area should delay berthing if at all possible during intense Scirocco as southerly winds blow across most piers. Angle is less severe at Maritime Station pier and berthing may be possible. On departure, expect wave heights to increase seaward.</p>	<p>a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Bora can be expected after 24 hr of southeasterly wind, often with rain. Southeasterlies normally last 6 hr or less.</p> <p>b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists.</p>
<p>4. <u>Small Boats</u></p> <p>Occurs year-round but most common in cool season. Feb is worst month.</p> <p>Occurs year-round.</p>	<p>a. ENE'ly winds - Bora Strong winds with limited waves heights. 50 kt gusting to 80 kt common in winter.</p> <p>b. S'ly winds - Scirocco Winds usually cover the entire Adriatic. Winds are cool in winter and hot in summer. Winds of 30 kt gusting to 45 kt are common.</p>	<p>a. Fleet Landing at Maritime Station is fairly well sheltered for small boats. Because waves are not excessive except in the most severe Boras, boating can continue in high winds. Low freeboard boats may have difficulty loading and offloading during strong Bora, especially if coincident with low tide.</p> <p>b. The Fleet Landing at Maritime Station is fairly well sheltered for small boats. Because waves are not excessive in the port area, boating can continue in high winds. Low freeboard boats may have difficulty in loading and offloading at Fleet Landing during low tide.</p>	<p>a. One tip-off to a coming Bora are clouds atop the mountains to the north which can be seen from the harbor. Also, if satellite pictures are available, note that cumulus cloud streaks can be seen if Bora is gale force (30+ kt) or more. Expect Bora conditions in the Adriatic when high pressure is forecast to build over the Balkans and/or a low pressure system is expected to move into the Ionian sea, especially from the Gulf of Genoa. Note that the strongest winds in a Bora episode are not usually at the outset. This factor may give at least some minimum warning time prior to taking precautionary actions. Bora can be expected after 24 hr of southeasterly wind, often with rain. Southeasterlies normally last 6 hr or less.</p> <p>b. One, almost foolproof rule, is that a Scirocco will occur when a depression or cyclone approaches the northern Adriatic Sea from the west or south. The onset of the Scirocco is much more gradual than the Bora so a longer warning period exists.</p>

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Port Visit Information

AUGUST, 1987. NEPRF meteorologists R. Fett and D. Perryman met with Port Captain Commander Gardella, Port Administrator Captain Bilucaglia, Corvette Captain Muner and Chief Pilot Captain Agostinis to obtain much of the information included in the port evaluation.

APPENDIX A

General Purpose Oceanographic Information

This section provides general information on wave forecasting and wave climatology as used in this study. The forecasting material is not harbor specific. The material in paragraphs A.1 and A.2 was extracted from H.O. Pub. No. 603, Practical Methods for Observing and Forecasting Ocean Waves (Pierson, Neumann, and James, 1955). The information on fully arisen wave conditions (A.3) and wave conditions within the fetch region (A.4) is based on the JONSWAP model. This model was developed from measurements of wind wave growth over the North Sea in 1973. The JONSWAP model is considered more appropriate for an enclosed sea where residual wave activity is minimal and the onset and end of locally forced wind events occur rapidly (Thornton, 1986), and where waves are fetch limited and growing (Hasselmann, et al., 1976). Enclosed sea, rapid onset/subsiding local winds, and fetch limited waves are more representative of the Mediterranean waves and winds than the conditions of the North Atlantic from which data was used for the Pierson and Moskowitz (P-M) Spectra (Neumann and Pierson 1966). The P-M model refined the original spectra of H.O. 603, which over developed wave heights.

The primary difference in the results of the JONSWAP and P-M models is that it takes the JONSWAP model longer to reach a given height or fully developed seas. In part this reflects the different starting wave conditions. Because the propagation of waves from surrounding areas into semi-enclosed seas, bays, harbors, etc. is limited, there is little residual wave action following periods of locally light/calm winds and

the sea surface is nearly flat. A local wind developed wave growth is therefore slower than wave growth in the open ocean where some residual wave action is generally always present. This slower wave development is a built in bias in the formulation of the JONSWAP model which is based on data collected in an enclosed sea.

A.1 Definitions

Waves that are being generated by local winds are called "SEA". Waves that have traveled out of the generating area are known as "SWELL". Seas are chaotic in period, height and direction while swell approaches a simple sine wave pattern as its distance from the generating area increases. An in-between state exists for a few hundred miles outside the generating area and is a condition that reflects parts of both of the above definitions. In the Mediterranean area, because its fetches and open sea expanses are limited, SEA or IN-BETWEEN conditions will prevail. The "SIGNIFICANT WAVE HEIGHT" is defined as the average value of the heights of the one-third highest waves. PERIOD and WAVE LENGTH refer to the time between passage of, and distances between, two successive crests on the sea surface. The FREQUENCY is the reciprocal of the period ($f = 1/T$) therefore as the period increases the frequency decreases. Waves result from the transfer of energy from the wind to the sea surface. The area over which the wind blows is known as the FETCH, and the length of time that the wind has blown is the DURATION. The characteristics of waves (height, length, and period) depend on the duration, fetch, and velocity of the wind. There is a continuous generation of small short waves from the time the wind starts until it stops. With continual transfer of energy from the wind to the sea

surface the waves grow with the older waves leading the growth and spreading the energy over a greater range of frequencies. Throughout the growth cycle a SPECTRUM of ocean waves is being developed.

A.2 Wave Spectrum

Wave characteristics are best described by means of their range of frequencies and directions or their spectrum and the shape of the spectrum. If the spectrum of the waves covers a wide range of frequencies and directions (known as short-crested conditions), SEA conditions prevail. If the spectrum covers a narrow range of frequencies and directions (long crested conditions), SWELL conditions prevail. The wave spectrum depends on the duration of the wind, length of the fetch, and on the wind velocity. At a given wind speed and given state of wave development, each spectrum has a band of frequencies where most of the total energy is concentrated. As the wind speed increases the range of significant frequencies extends more and more toward lower frequencies (longer periods). The frequency of maximum energy is given in equation 1.1 where v is the wind speed in knots.

$$f_{\max} = \frac{2.476}{v} \quad (1.1)$$

The wave energy, being a function of height squared, increases rapidly as the wind speed increases and the maximum energy band shifts to lower frequencies. This results in the new developing smaller waves (higher frequencies) becoming less significant in the energy spectrum as well as to the observer. As larger waves develop an observer will pay less and less attention to the small waves. At the low frequency (high period) end

the energy drops off rapidly, the longest waves are relatively low and extremely flat, and therefore also masked by the high energy frequencies. The result is that 5% of the upper frequencies and 3% of the lower frequencies can be cut-off and only the remaining frequencies are considered as the "significant part of the wave spectrum". The resulting range of significant frequencies or periods are used in defining a fully arisen sea. For a fully arisen sea the approximate average period for a given wind speed can be determined from equation (1.2).

$$\bar{T} = 0.285v \quad (1.2)$$

Where v is wind speed in knots and \bar{T} is period in seconds. The approximate average wave length in a fully arisen sea is given by equation (1.3).

$$\bar{L} = 3.41 \bar{T}^2 \quad (1.3)$$

Where \bar{L} is average wave length in feet and \bar{T} is average period in seconds.

The approximate average wave length of a fully arisen sea can also be expressed as:

$$\bar{L} = .67"L" \quad (1.4)$$

where " L " = $5.12T^2$, the wave length for the classic sine wave.

A.3 Fully Arisen Sea Conditions

For each wind speed there are minimum fetch (n mi) and duration (hr) values required for a fully arisen sea to exist. Table A-1 lists minimum fetch and duration values for selected wind speeds, values of significant wave (average of the highest 1/3 waves)

period and height, and wave length of the average wave during developing and fully arisen seas. The minimum duration time assumes a start from a flat sea. When pre-existing lower waves exist the time to fetch limited height will be shorter. Therefore the table duration time represents the maximum duration required.

Table A-1. Fully Arisen Deep Water Sea Conditions Based on the JONSWAP Model.

Wind Speed (kt)	Minimum Fetch/Duration (n mi) (hrs)		Sig Wave (H1/3 Period/Height (sec) (ft)		Wave Length (ft) ^{1,2}	
					Developing/Fully Arisen	
					L X (.5)	/L X (.67)
10	28 /	4	4 /	2	41 /	55
15	55 /	6	6 /	4	92 /	123
20	110 /	8	8 /	8	164 /	220
25	160 /	11	9 /	12	208 /	278
30	210 /	13	11 /	16	310 /	415
35	310 /	15	13 /	22	433 /	580
40	410 /	17	15 /	30	576 /	772

NOTES:

- 1 Depth throughout fetch and travel zone must be greater than 1/2 the wave length, otherwise shoaling and refraction take place and the deep water characteristics of waves are modified.
- 2 For the classic sine wave the wave length (L) equals 5.12 times the period (T) squared ($L = 5.12T^2$). As waves develop and mature to fully developed waves and then propagate out of the fetch area as swell there wave lengths approach the classic sine wave length. Therefore the wave lengths of developing waves are less than those of fully developed waves which in turn are less than the length of the resulting swell. The factor of .5 (developing) and .67 (fully developed) reflect this relationship.

Wave Conditions Within The Fetch Region

Waves produced by local winds are referred to as SEA. In harbors the local sea or wind waves may create hazardous conditions for certain operations. Generally within harbors the fetch lengths will be short and therefore the growth of local wind waves will be fetch limited. This implies that there are locally determined upper limits of wave height and period for each wind velocity. Significant changes in speed or direction will result in generation of a new wave group with a new set of height and period limits. Once a fetch limited sea reaches its upper limits no further growth will occur unless the wind speed increases.

Table A-2 provides upper limits of period and height for given wind speeds over some selected fetch lengths. The duration in hours required to reach these upper limits (assuming a start from calm and flat sea conditions) is also provided for each combination of fetch length and wind speed. Some possible uses of Table A-2 information are:

- 1) If the only waves in the area are locally generated wind waves, the Table can be used to forecast the upper limit of sea conditions for combinations of given wind speeds and fetch length.
- 2) If deep water swell is influencing the local area in addition to locally generated wind waves, then the Table can be used to determine the wind waves that will combine with the swell. Shallow water swell conditions are influenced by local bathymetry (refraction and shoaling) and will be addressed in each specific harbor study.
- 3) Given a wind speed over a known fetch length the maximum significant wave conditions and time needed to reach this condition can be determined.

Table A-2. Fetch Limited Wind Wave Conditions and Time Required to Reach These Limits (Based on JONSWAP Model). Enter the table with wind speed and fetch length to determine the significant wave height and period, and time duration needed for wind waves to reach these limiting factors. All of the fetch/speed combinations are fetch limited except the 100 n mi fetch and 18 kt speed.

Format: height (feet)/period (seconds)
duration required (hours)

Fetch \ Length \ (n mi)	Wind Speed (kt)				
	18	24	30	36	42
10	2/3-4 1-2	3/3-4 2	3-4/4 2	4/4-5 1-2	5/5 1-2
20	3/4-5 2-3	4/4-5 3	5/5 3	6/5-6 3-4	7/5-6 3
30	3-4/5 3	5/5-6 4	6/6 3-4	7/6 3-4	8/6-7 3
40	4-5/5-6 4-5	5/6 4	6-7/6-7 4	8/7 4	9-10/7-8 3-4
100	5/6-7 ¹ 5-6	9/8 8	11/9 7	13/9 7	15-16/9-10 7

¹ 18 kt winds are not fetch limited over a 100 n mi fetch.

An example of expected wave conditions based on Table A-2 follows:

WIND FORECAST OR CONDITION

An offshore wind of about 24 kt with a fetch limit of 20 n mi (ship is 20 n mi from the coast) is forecast or has been occurring.

SEA FORECAST OR CONDITION

From Table A-2: If the wind condition is forecast to last, or has been occurring, for at least 3 hours:

Expect sea conditions of 4 feet at 4-5 second period to develop or exist. If the condition lasts less than 3 hours the seas will be lower. If the condition lasts beyond 3 hours the sea will not grow beyond that developed at the end of about 3 hours unless there is an increase in

wind speed or a change in the direction that results in a longer fetch.

A.5 Wave Climatology

The wave climatology used in these harbor studies is based on 11 years of Mediterranean SOWM output. The MED-SOWM is discussed in Volume II of the U.S. Naval Oceanography Command Numerical Environmental Products Manual (1986). A deep water MED-SOWM grid point was selected as representative of the deep water wave conditions outside each harbor. The deep water waves were then propagated into the shallow water areas. Using linear wave theory and wave refraction computations the shallow water climatology was derived from the modified deep water wave conditions. This climatology does not include the local wind generated seas. This omission, by design, is accounted for by removing all wave data for periods less than 6 seconds in the climatology. These shorter period waves are typically dominated by locally generated wind waves.

A.6 Propagation of Deep Water Swell Into Shallow Water Areas

When deep water swell moves into shallow water the wave patterns are modified, i.e., the wave heights and directions typically change, but the wave period remains constant. Several changes may take place including shoaling as the wave feels the ocean bottom, refraction as the wave crest adjusts to the bathymetry pattern, changing so that the crest becomes more parallel to the bathymetry contours, friction with the bottom sediments, interaction with currents, and adjustments caused by water temperature gradients. In this work, only shoaling and refraction effects are

considered. Consideration of the other factors are beyond the resources available for this study and, furthermore, they are considered less significant in the harbors of this study than the refraction and shoaling factors.

To determine the conditions of the deep water waves in the shallow water areas the deep water conditions were first obtained from the Navy's operational MED-SOWM wave model. The bathymetry for the harbor/area of interest was extracted from available charts and digitized for computer use. Figure A-1 is a sample plot of bathymetry as used in this project. A ray path refraction/shoaling program was run for selected combinations of deep water wave direction and period. The selection was based on the near deep water wave climatology and harbor exposure. Each study area requires a number of ray path computations. Typically there are 3 or 4 directions (at 30° increments) and 5 or 6 periods (at 2 second intervals) of concern for each area of study. This results in 15 to 24 plots per area/harbor. To reduce this to a manageable format for quick reference, specific locations within each study area were selected and the information was summarized and is presented in the specific harbor studies in tabular form.

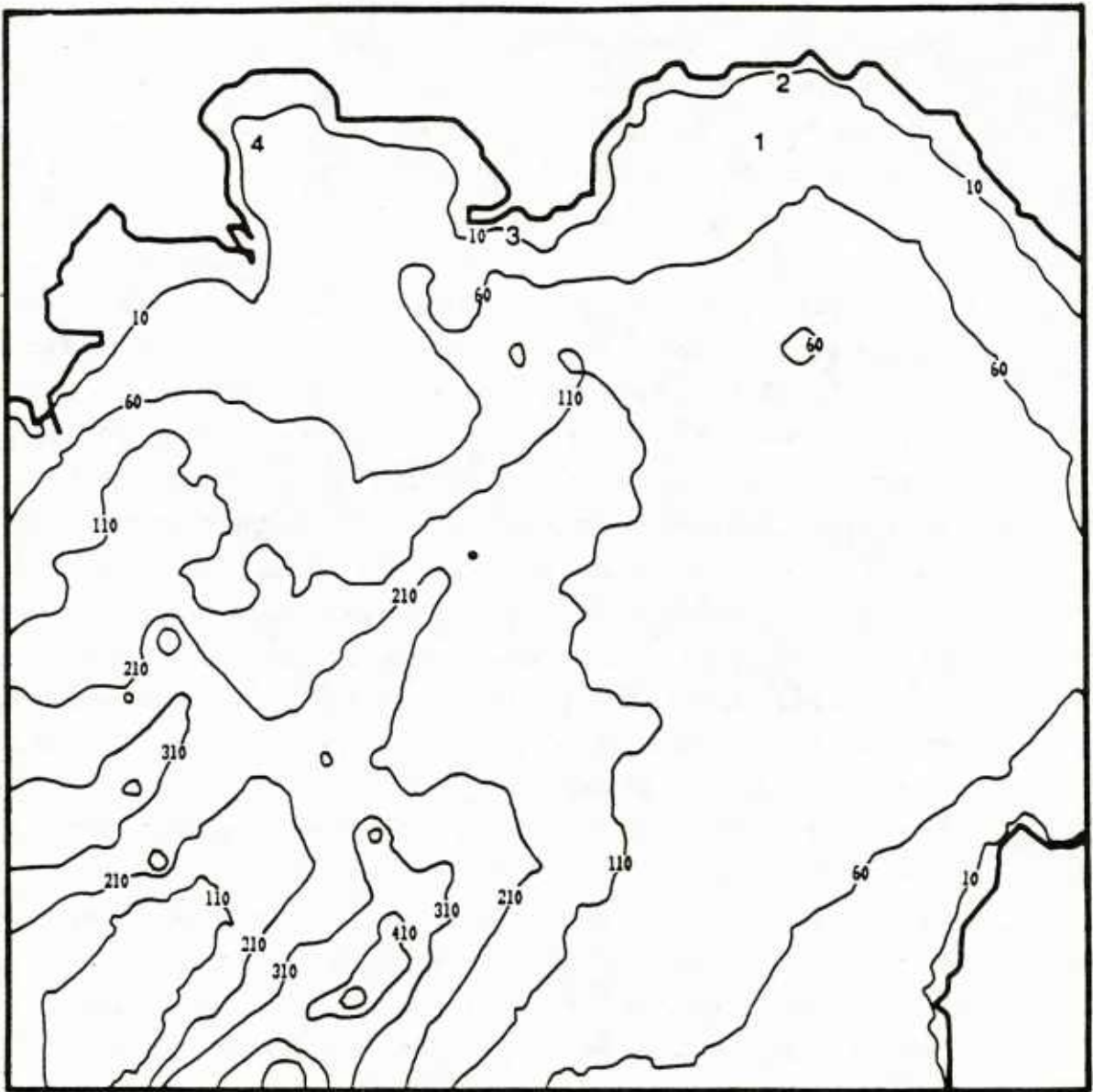


Figure A-1. Example plot of bathymetry (Naples harbor) as used in this project. For plotting purposes only, contours are at 50 fathom intervals from an initial 10 fathom contour. The larger size numbers identify specific anchorage areas addressed in the harbor study.

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